CHANGES IN THE COMMUNITY STRUCTURE OF BENTHIC MACROINVERTEBRATES IN THE STONY-BED AREAS OF THE PALMIET RIVER, IN RELATION TO THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE RIVER

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ABSTRACT

An investigation of the benthic macroinvertebrates at five sites along the Palmiet River was made to determine the nature of the faunal communities and their relation to physical and chemical conditions of the water. Stony-bed areas were sampled with a Surber-type sampler, while temperature, flow rate, pH and levels of dissolved oxygen, silicates, phosphates, nitrates and nitrites were measured at the same time. Data were analysed by cluster analyses, information test statistics and stepwise multiple regression analyses of species diversity vs flow-rate. It was found that flow rate was the only parameter significantly correlated with species diversity. Variations in the structure of communities down the length of the river were related to the effect of changes in the catchment area on the physico-chemical parameters. It is concluded that winter spates have the greatest effect on community structure and suggested that the effects of agricultural and urban development are limited to the low flow periods during summer. A call is made for a reconsideration of the proposed Hangklip Dam, not only for the conservation of the unique Kogelberg State Forest, but because a dam in the lower reaches of the river will mean the loss of the last remaining perennial river in the Western Cape which flows unimpeded to the sea.

INTRODUCTION

South Africa's demand for water has left its mark in the form of large storage reservoirs on most perennial rivers in the Western Cape. One notable exception is the Palmiet River which, unlike the Breede, Olifants and Riviersonderend Rivers, has no storage dam on it to serve Cape Town. The probability of a water shortage in the city has already stimulated plans for such a dam on the river's lower reaches. The Palmiet River is already subjected to water utilization by urban and agricultural development, although this does not regulate the flow of the river completely, leaving it in a relatively natural condition.

Noble and Hemens (1978) have emphasised the need for exploratory surveys of rivers in South Africa to assist in the formulation of a scientific basis for their management and utilization. Changes in the river induced by human activities, for example, water extraction, pollution and damming can only be examined accurately from baseline studies of their natural status. Few studies of this nature have been undertaken in the Western Cape, apart from the pioneering work done by Harrison and Elsworth (1958) on the Berg River. Recently King (1981) has made a detailed analysis of the zoobenthos of the Eerste River, relating the faunal patterns to the physical and chemical characteristics of the river water.

The aim of this study was to follow changes in the structure of the macro invertebrate communities down the length of the Palmiet River and to

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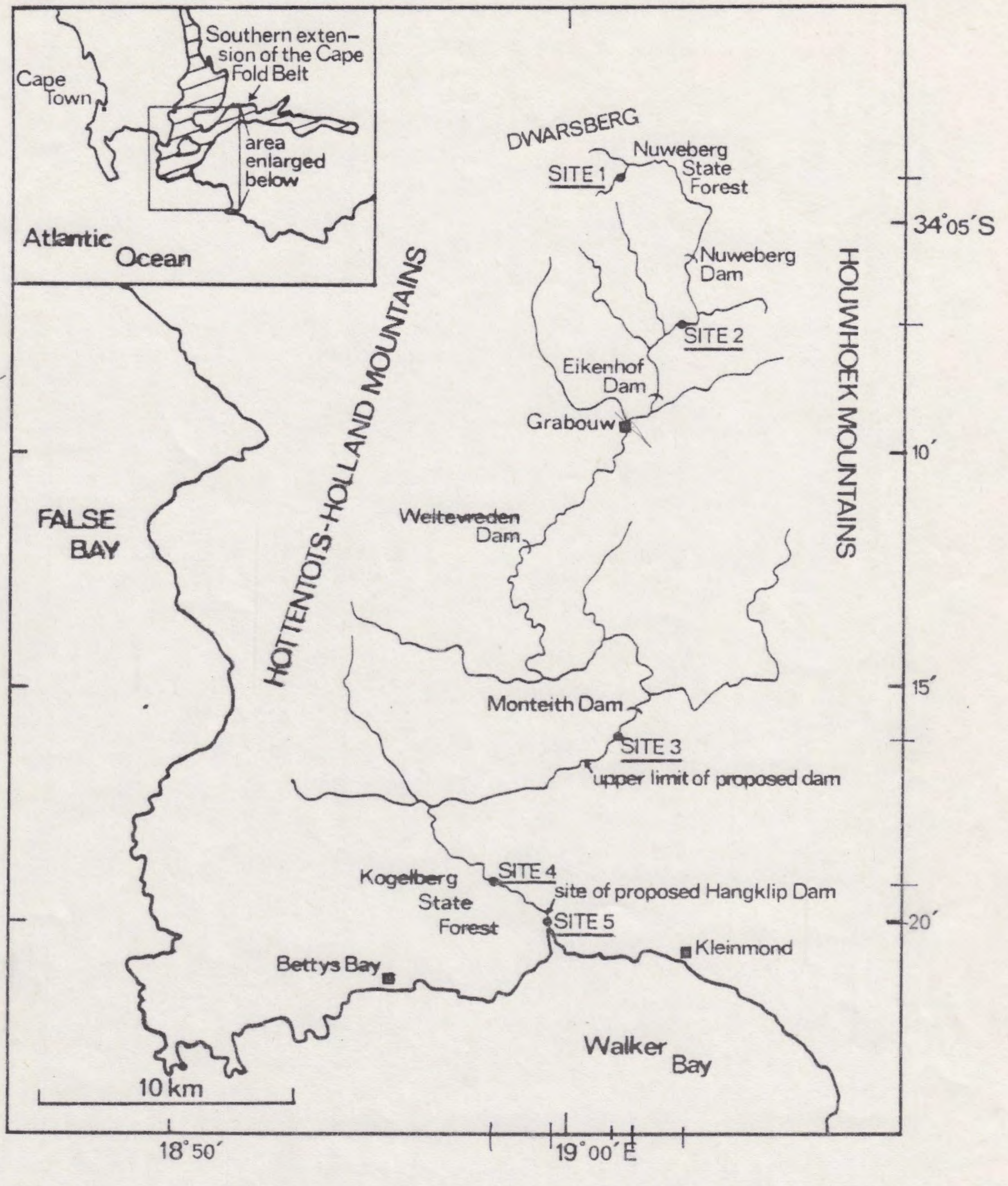

Figure 1 Map of Palmiet River catchment area showing the Palmiet River with major tributaries, sampling sites, present dams, proposed Hangklip Dam and main mountain ranges indicated. Shaded area in the inset indicates the southern extension of the Cape Fold Belt.

try to relate changes in these communities to the physical and chemical characteristics of the water. These characteristics, in turn, could be related to changes in the river's catchment area; studying the zoobenthos could therefore give clues to the effect human activities have on the river.

The motivation for the study stemmed from the need to obtain some information about the Palmiet River before its lower reaches are inundated by the proposed Hangklip Dam. One of the proposed sites for the dam wall is a few kilometres above the estuary (Figs 1 & 2). When full, the dam will flood approximately 18 kilometres of the lower reaches of the river, which lies within the valuable Kogelberg State Forest. This is one of the last areas of pure montane fynbos, of which 34 rare species will be seiously threatened by the dam.

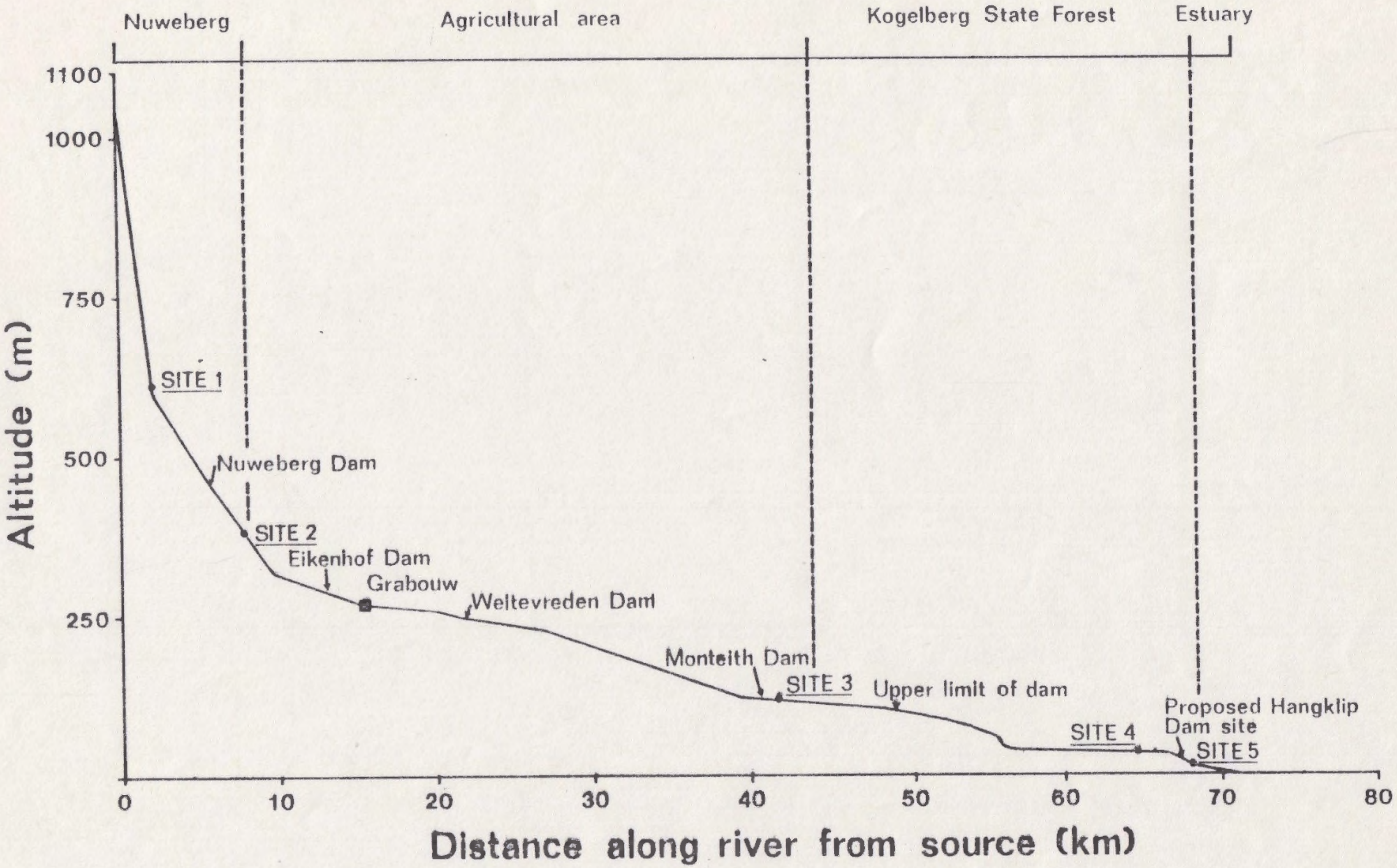

Figure 2 Profile of the Palmiet River with sampling sites, present dams, proposed Hangklip Dam, zones in the catchment area and Grabouw indicated.

STUDY AREA

The Palmiet River is a perennial, 71 kilometre long river, which arises in the Dwarsberg of the Hottentots-Holland range, approximately 60 km south-east of Cape Town (Fig. 1). The river follows the syncline of the southern extent of the Cape Fold Belt (Fig. 1, inset) and enters the sea at Walker Bay, where the mountains cut the coastal lowland plain, and abut into the sea (Heydorn & Tinley 1980). Consequently the river has a steep profile (Fig. 2), with an average gradient of 14,6 m km^{-1}. The catchment area lies in the winter-rainfall area of the Western Cape and can receive over 2500 mm rain per year, due to the high mountains. Despite its relatively small catchment area (500 km^2) the river discharges an average of 310×10^6 m^3 water per year, up to three times as much as the neighbouring Bot and Klein Rivers (Heydorn & Tinley 1980). The high discharge occurs mainly during winter spates.

Over most of its catchment area the Palmiet River drains Table Mountain Sandstone-derived, acid leached soils (Lambrecht 1979) which give the river a "black-water" appearance. This water is typical of the rivers draining the fynbos (Cape heathland) areas of the Western Cape, being very low in nutrients and highly acidic (pH range 3-5; Noble & Hemens 1978), with a low silt load and total dissolved solids (King & Day 1979).

Along most of its course, the river is lined by the palmiet reed, *Prionum serratum*, from which it derives its name. Three main zones

(Fig. 2) can be discerned in the catchment area (not the same as true riverine zones). The headwaters and first 10 kilometres run through mountain fynbos and pine forests (*Pinus radiata*), which are replaced by apple orchards for the next 34 kilometres. This reach is lined by stands of black wattle (*Acacia mearnsii*), Port Jackson willow (*A. saligna*), *Eucalyptus* spp., cluster pines (*Pinus pinaster*) and other alien vegetation. Grabouw is the only town along the river, lying approximately 15 kilometres from its source. Effluent from fruit factories and sewage treatment works are discharged here into the river, which meanders through dense stands of *Prionum* along this stretch.

Over the last 24 kilometres of its course (the third zone), the Palmiet River flows through the Kogelberg State Forest. The shape of the valley just above the estuary seems to make this area an ideal site for the proposed Hangklip Dam. At the present time there are four earthen dams on the Palmiet River (Figs 1 & 2). The Nuweberg and Eikenhof Dams are above Grabouw and the dams on Weltevreden and Monteith farms are between Grabouw and the Kogelberg Reserve.

METHODS

Sampling sites

Samples were collected at five sites along the river (Figs 1 & 2 and Plates 1-6) in March and August 1981. These are numbered 1 - 5 downstream and referred to as 1S - 5S in March (Summer) and 1W - 5W in August (Winter). Details of each sampling site are given in Table 1. Due to the rocky nature of the river-bed, depths varied very much along the river. At all the sampling sites (and even to right above the estuary) maximum water depth was less than 1,5 m. In the lower reaches of the river (between sites 3 and 4), the river-bed is transected by stony ridges, behind which the river may attain depths of more than 2 m.

Physical and chemical conditions

In the field, oxygen was measured with a YSI O_2 meter, temperature with a field thermometer and pH with Merck Universal indicator paper. Flow-rates were estimated by measuring distance-over-time with a neutral density object. Water samples were taken at each site in polythene containers and frozen immediately on dry ice. These water samples were analysed for silicates, total phosphate-phosphorus, nitrite-nitrogen and nitrate-nitrogen using a Technicon autoanalyzer.

Faunal samples

Samples were taken of the stony-bed benthic macroinvertebrates using

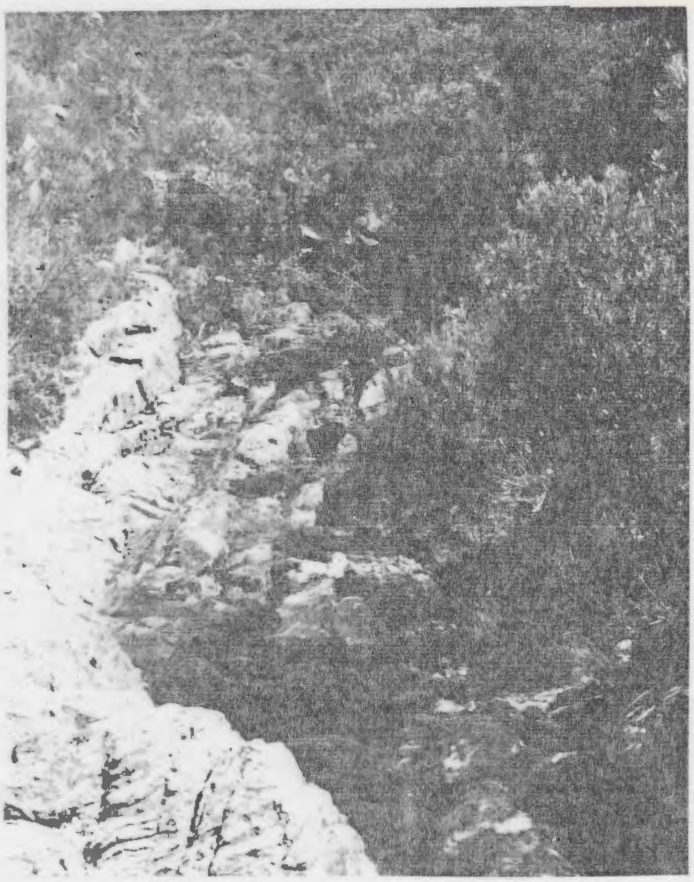

Plate 1 Sampling site 1 in March. Note montane fynbos on slopes.

Plate 2 Sampling site 2 in March. Note stands of *Prionum serratum* in river and *Eucalyptus* trees on river-bank. The square framed object is the Surber sampler.

TABLE 1 Description of sampling sites on Palmiet River

Site No.	Distance (km) from source	Altitude (m)	Surrounding vegetation	Width (m)	General
1	1,9	600	Fynbos, pine	5	Typical mountain stream
2	6,0	327	*Eucalyptus*	10	High river banks, deep shade
3	45,4	114	A. *saligna*	25	Long, deep pools upstream and downstream
4	65,0	38	Fynbos	40	Bare bedrock, almost no sediment
5	69,0	7	Fynbos	50	Bare bedrock, almost ro sediment

Plate 3 Sampling site 3 in August. Note stands of *Prionum serratum* in river and *Acacia saligna* on river-banks.

Plate 4 Sampling site 4 in March, looking upstream. Note montane fynbos in valley, which will be flooded by the Hangklip Dam.

Plate 5 Sampling site 4 in March, looking downstream. Note well-scoured bedrock with small stands of *Prionum serratum*. The arrow indicates the approximate height and portion of the proposed Hangklip Dam.

Plate 6 Sampling site 5 in March, looking upstream. Note extensive stands of *Pronium serratum*. The arrow indicates the approximate height and position of the proposed Hangklip Dam.

a Surber-type square-frame sampler. The sampler consists of a collapsible steel frame of dimensions 0,5 m x 0,5 m x 0,5 m. A net of 0,6 mm nybolt monofilament mesh is attached to the downstream side and the other three vertical sides (upstream, riverbank and midstream sides) are covered by cloth. The bottom frame encloses an area of 0,25 m^2 and has a sturdy rubber fringe to prevent animals from escaping or entering. The top of the sampler is open to be able to remove stones from the enclosed area so that animals could be taken off them. Animals, on or below stones, which were dislodged were carried into the net by the current. Once all the stones had been removed, the enclosed area was stirred well with a sturdy stick to dislodge any animals still on the bottom. All animals collected were placed in 70 percent alcohol. Specimens were later identified as far as possible. Two samples were taken at each site and the results pooled.

<u>Statistical analysis</u>

Simpson's species diversity index (Simpson 1949) was calculated for the fauna caught at each sampling site, using the formula:

$$D = \frac{N\,(N-1)}{\sum_{i=1}^{k} n_i\,(n_i-1)}$$

where D = diversity index

N = the total number of individuals at a sampling site

n = the total number of individuals of the ith species

k = the number of species present at the sampling site

The index ranges from 1.0, when all the individuals belong to one species, to infinity, when each individual belongs to a different species.

Relationships between the calculated species diversity indices and physical and chemical parameters were then investigated using the Madison stepwise multiple linear regression analysis (Allen 1973).

Both physico-chemical parameters and faunal communities show transitional longitudinal variation, rather than discrete zones in a river (Hynes 1970). However, the data of each sampling site were treated as separable sets for the purposes of the following statistical analyses. Similarities between sampling sites (for both physico-chemical and faunal data) were investigated using the Bray-Curtis similarity measure (Bray & Curtis 1957). The data for this determination were log-transformed, and then presented as a dendrogram, which uses classification by the group-average sorting method (Lance & Williams 1967). The dendrogram clusters similar samples together and gives an indication of the percentage similarity between the samples. This analysis is used in conjunction with ordination, derived by multi-dimensional scaling (Field & McFarlane 1968), which plots samples as points on a x-y plane. When the plot is considered with the dendrogram, the samples can be separated into groups, which cluster similar samples together. Some distortion can happen when the samples are projected from a 4-dimensional matrix onto an x-y plane, but used with the dendrogram, this analysis gives a good idea of relative similarities.

The faunal communities identified from the cluster analysis were subsequently subjected to information statistics tests (Field 1969; Velimirov *et al.* 1977) to determine which species differ significantly ($p < 0{,}01$) in frequency of occurrence between communities. This technique is useful for determining "indicator" species, which are typical of any one community. Further it is useful for showing up species (normally occurring in other communities) whose unnatural occurrence serves as indicators of ecological disturbance.

RESULTS

Physical and chemical conditions

Table 2 and Figs 3 and 4 show the results of all the measured physico-chemical parameters. At all the sampling sites in both March and August, the water had a pH of 5, typical of the acid western Cape mountain streams. Dissolved oxygen levels were almost constantly above 100 percent saturation (corrected for altitude and temperature), except at site 3S (85% saturation).

Flow-rates (Fig. 4) were variable, but seem to be higher, on the whole, at each site in winter with a concommitant increase downstream.

Temperatures were much reduced during winter (Table 2) compared to summer, and on both occasions tended to increase downstream.

Sites 1 and 2 generally reflected the oligotrophic nature of black waters, especially during summer. In winter nutrient levels rose at these sites, probably due to increased runoff (Fig. 3). Almost all the nutrients show an increase in the river from site 3 downstream. Nitrate levels show a dramatic increase (Fig. 3) in both winter and summer at site 3, with maximum levels almost three times higher in winter.

<u>Cluster analysis</u>: All the sites were very similar to each other, having a minimum of 84 percent similarity (Fig. 5). This is probably due to the relatively constant pH, dissolved oxygen levels and

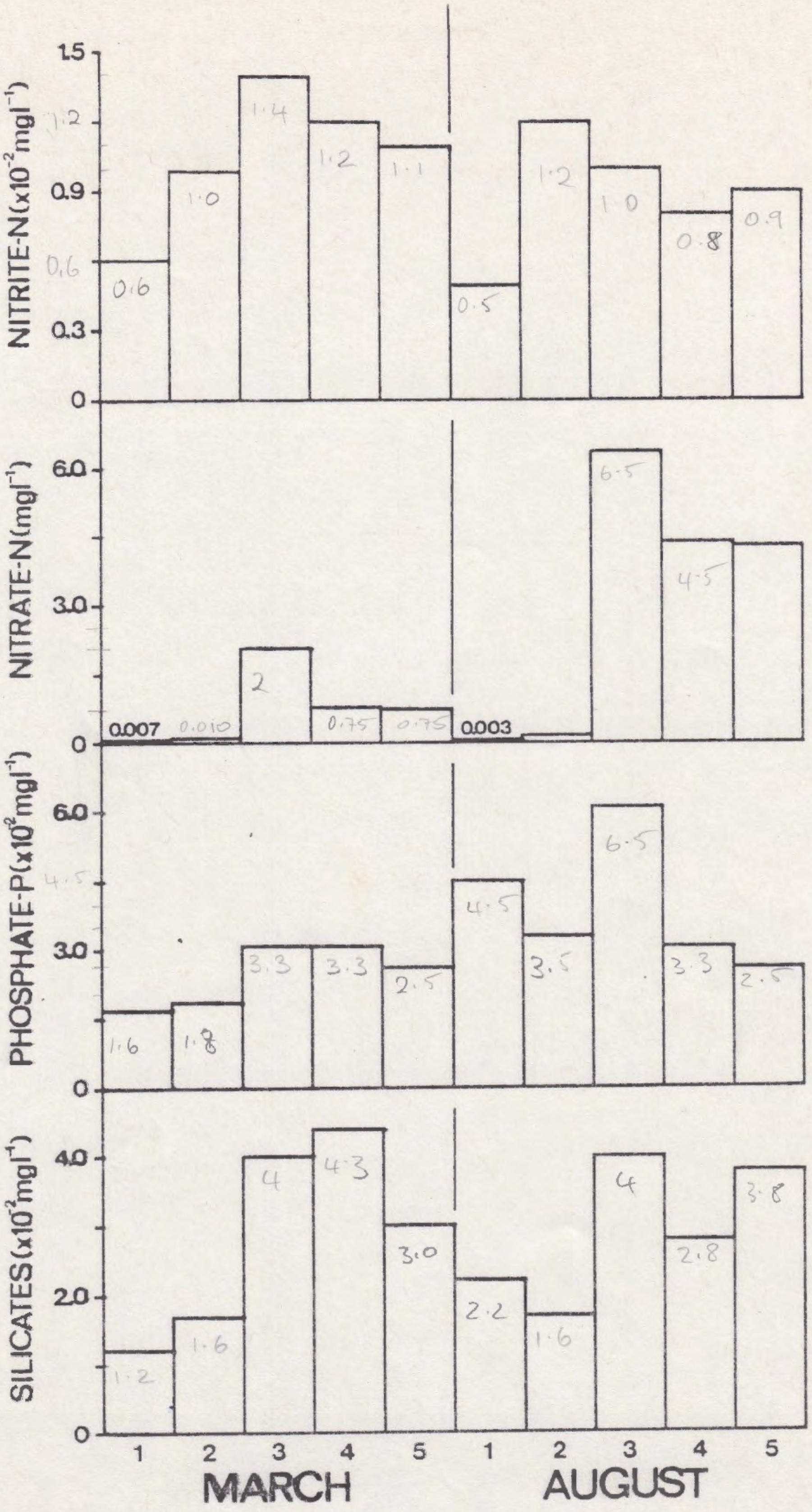

Figure 3 Levels of silicates, total phosphate-phosphorus nitrate-nitrogen and nitrite-nitrogen at the Palmiet River sampling sites (1-5) in March and August.

TABLE 2 Temperature (°C), pH and levels of dissolved oxygen (% saturation) at the Palmiet River sampling sites in March and August.

	SAMPLING SITES									
	MARCH					AUGUST				
	1	2	3	4	5	1	2	3	4	5
Dissolved O_2 (% of saturation)	112	111	85	113	106	110	109	106	104	113
Temperature (°C)	17,8	10,0	20,5	22,2	21,5	10,2	12,0	10,0	13,5	13,7
pH	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0

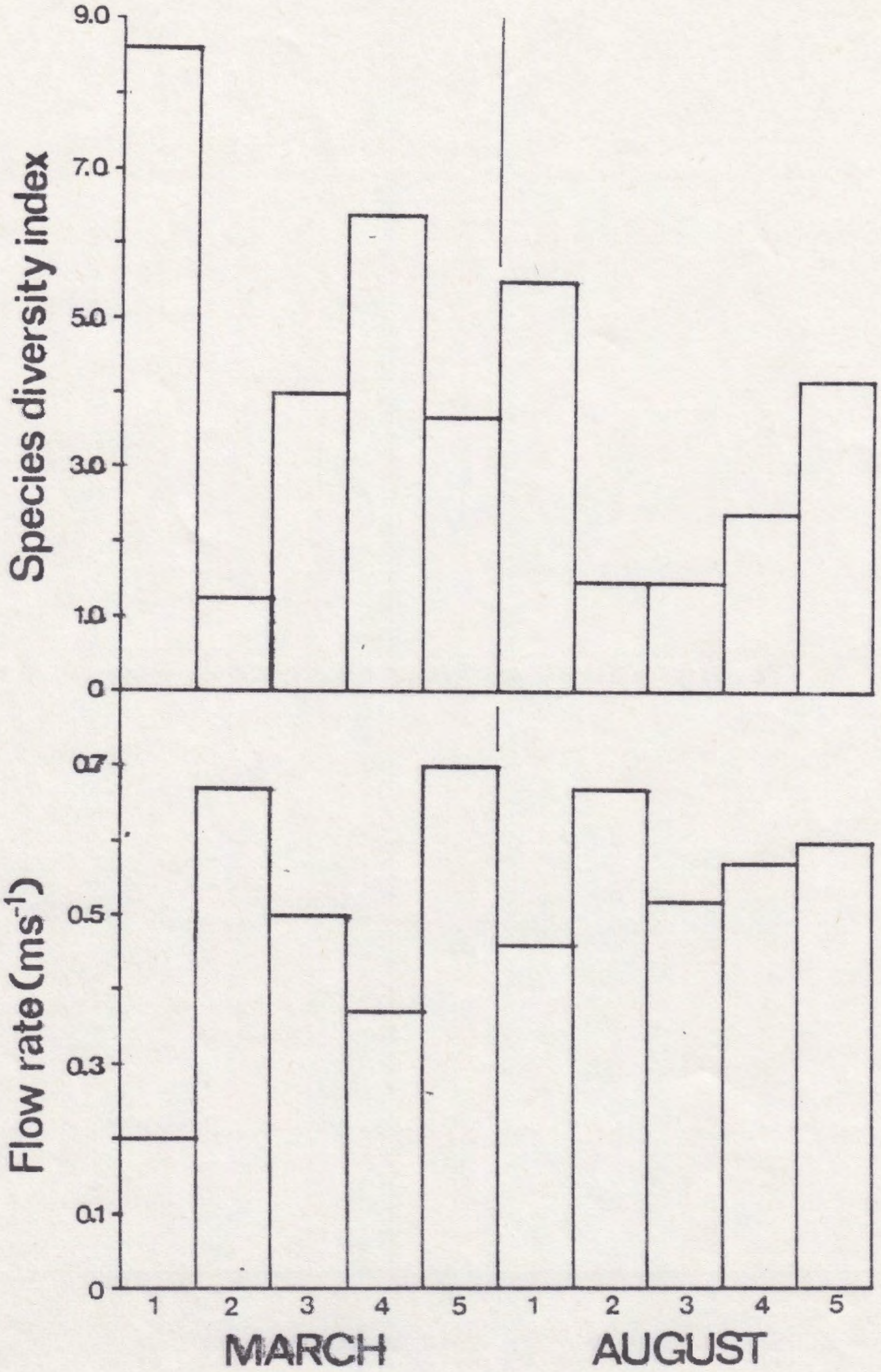

Figure 4 Flow rates (m.s^{-1}) and species diversity (Simpson's index) at the Palmiet River sampling sites (1-5) in March and August.

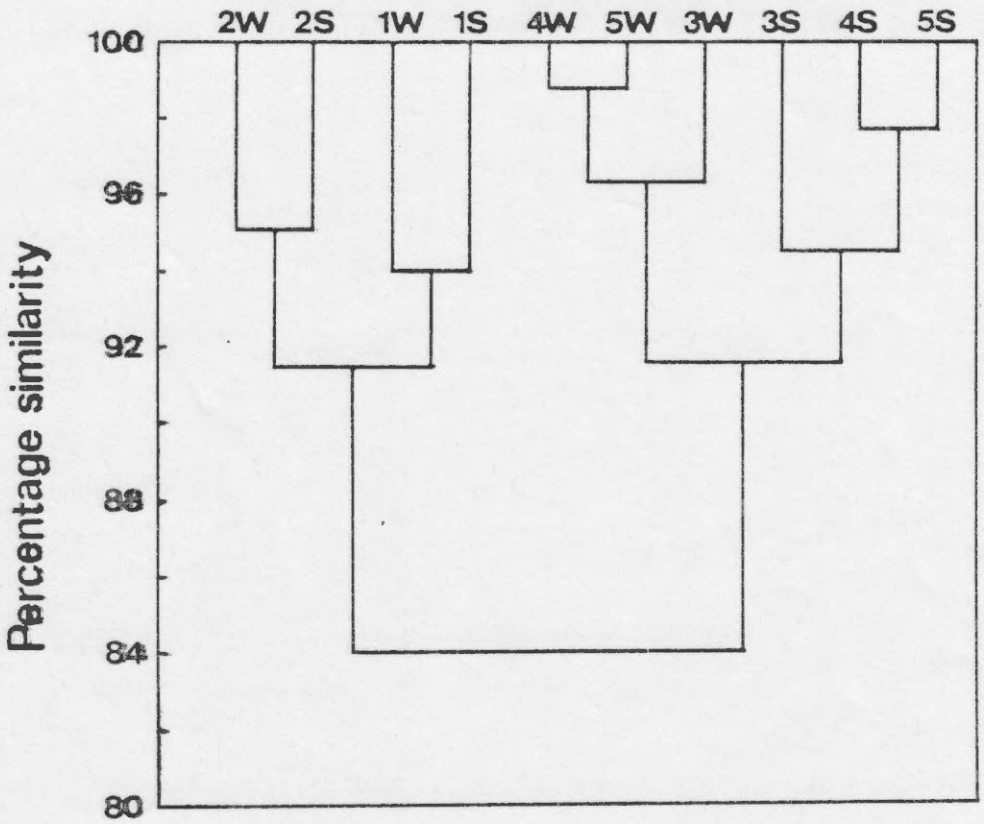

Figure 5 Dendrogram of the physico-chemical parameters at the Palmiet River sampling sites (1-5) in March (S) and August (W).

(seasonally) temperature. At an arbitrary 90 percent similarity level on the dendrogram, one can see a division into an upstream (above Grabouw) component (sites 1 & 2) and a downstream component (sites 3, 4 & 5). These groups are clearly divided in the ordination plot (Fig. 6) by the y-axis. This longitudinal division is probably due to the increased nutrient levels from site 3 onwards. At a 93 percent similarity level in the dendrogram, four groups are formed, which correspond with the groups formed in the ordination plot. A clear division into seasons can be seen above and below the x-axis, especially in the downstream component. Sites 1S and 1W, and 2S and 2W are grouped together, indicating less seasonal variation than at sites 3, 4 and 5, which show greater seasonal than longitudinal variation. The seasonal variation is probably due to differences in temperature, flow rates and nutrient concentrations at the downstream sampling sites.

Faunal samples

Figure 7 shows the percentage composition of the fauna, and the number of species present at each sampling site during March and August. Actual numbers of individuals of each group caught at each site, are given in Appendix 1. Only major groups (for example Ephemeroptera, Gastropoda) are included in Fig. 7 if the total number of individuals of the group constitute more than 5 percent of the total number of individuals caught. It is apparent from Fig. 7 (and Appendix 1) that there are fewer species at each site during winter than during summer, despite an increase in the number of individuals caught at sites 1, 3

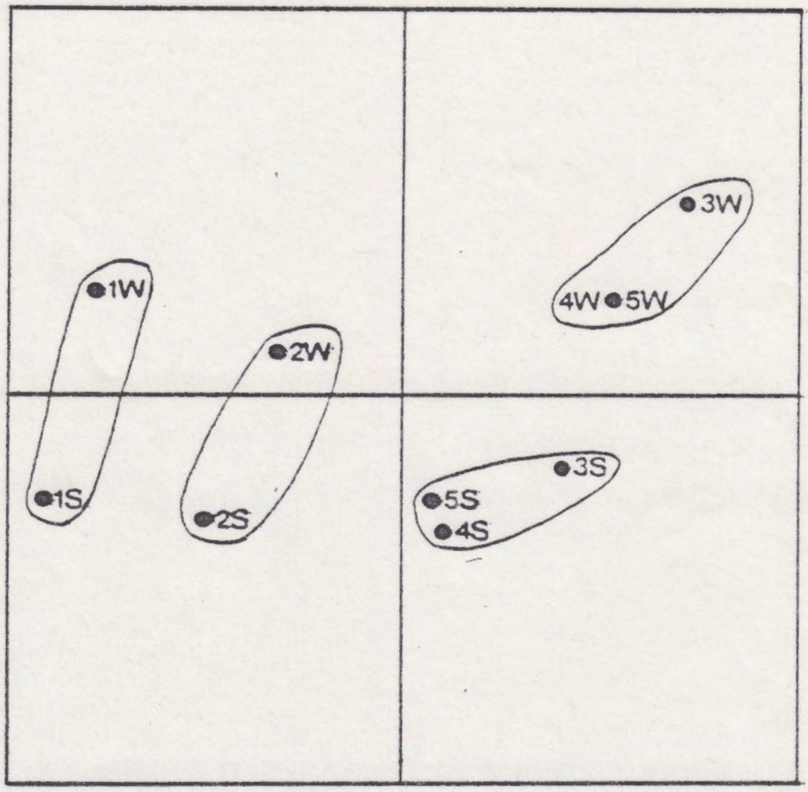

Figure 6 Two-space ordination diagram of the physico-chemical parameters at the Palmiet River sampling sites (1-5) in March (S) and August (W). Groups are as in Fig. 5 at the 93 percent similarity level. Stress = 1,2% (acceptable, Levine 1978).

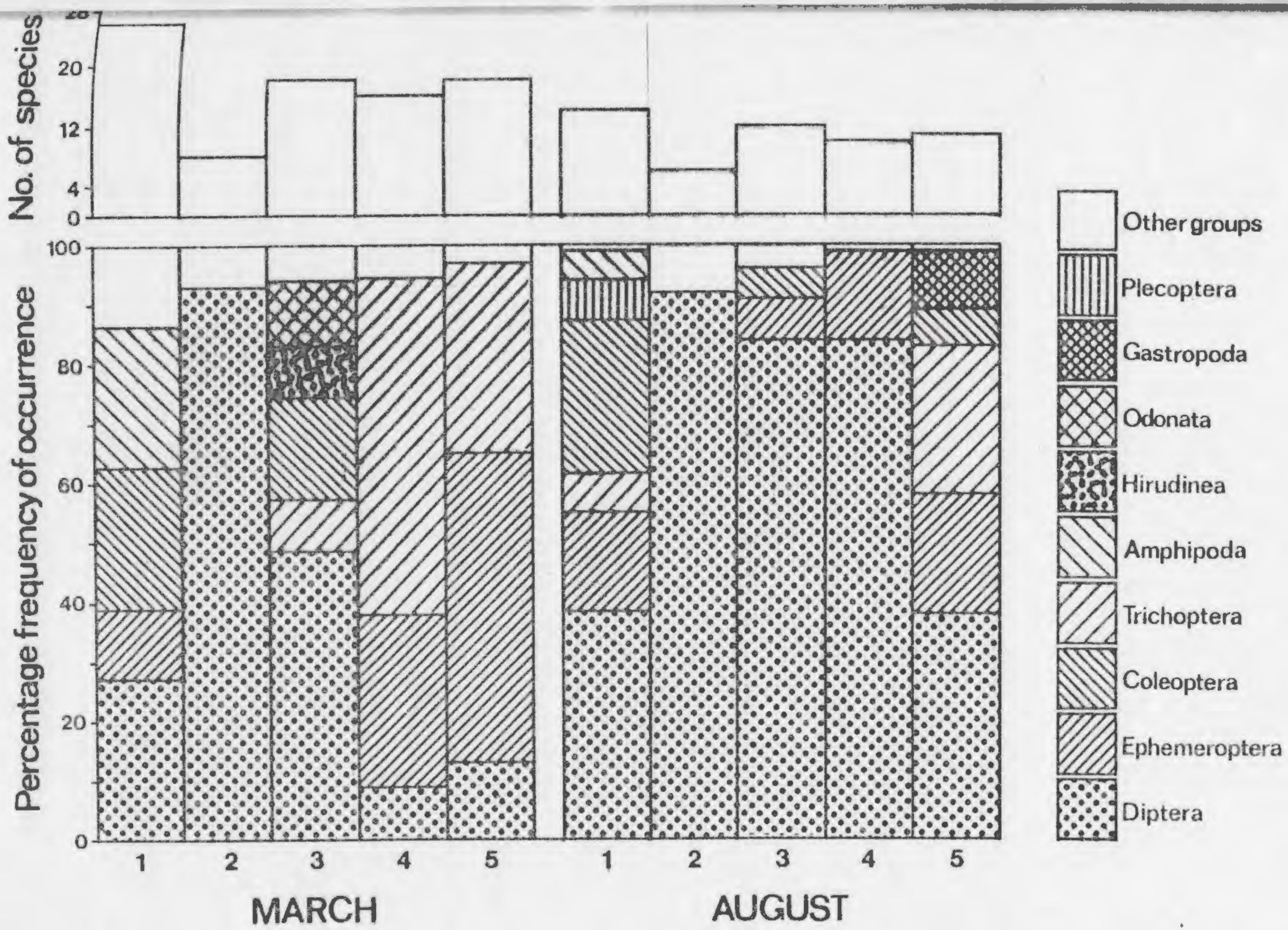

Figure 7 Composition of the communities and the number of species of benthic macroinvertebrates at the Palmiet River sampling sites (1-5) in March and August. Only groups constituting more than 5 percent of the total number individuals caught at any site are indicated.

and 4 in August. The number of species is highest, in both seasons, at site 1, drops drastically at site 2, and then maintains a fairly constant elevated level from site 3 downstream (Fig. 7). Insects account for more than 88 percent of all the individuals at all the sampling sites, except at site 1S, where their contribution is depressed by the numbers of the amphipod *Gammarus* (24,0%) present. The only other significant non-insect invertebrates present are Hirudinea (7,8%) at site 3S and the gastropod *Burnupia capensis* (9,7%) at siteW. The dominance of Diptera (mainly Simuliidae) at sites 2S and 3S, and their increase at sites 3W, 4W and 5W is also apparent from Fig. 7. Ephemeroptera were mainly present at sites 1, 3 and 5 in both March and August, while Trichoptera occurred mainly below site 3. Coleoptera were present at all the sites, except site 2W and were a large group at sites 1S, 1W and 3S. Plecoptera and Odonata were scarce, occurring only significantly at sites 1W and 3S respectively. The remaining groups (Megaloptera, Ephemeroptera and Hemiptera were never significantly represented.

Information statistics tests

In these tests, "indicator" species, or "typical" species, are indicated only when they occur in one of two groups under comparison, and the difference in occurrence is significant at the 99 percent confidence level. Indicators of summer species, determined in this way, were *Tricorythus discolor*, *Helothemis* sp., *Macronema* sp. and a pupa of hydroptilid ~~beetle~~ trichopteran. The only significant indicator species of winter conditions was *Ephemerellina penicillata*, although *Orthotrichia* sp. was the only other species which only occurred in winter.

Comparing upstream (above Grabouw, sites 1 and 2) with downstream sites (sites 3, 4 and 5) it was found that *Gammarus*, a helodid species and a ptilodactylid species were indicators of upstream conditions, while *Ephemerellina penicillata*, *Helothemis* sp., *Aeschna minuscula*, *Macronema* sp. and *Burnupia capensis* were all typical of the lower reaches.

At site 1, the tests showed no single species to be typical of summer conditions, while only *Aphanicerca* sp. was indicative of winter conditions. The simuliids were the only group significantly different between seasons at site 2 and occurred more during *summer* than during winter. Site 3 had 5 species typical of summer conditions of which *Helothemis* sp., *Burnupia capensis* and a dryopid species were most important. There were no typically winter species, although Simuliidae reached high numbers at this site. The most significant change from summer to winter conditions at site 4 was in the number of simuliids, which increased almost fifteenfold. The species typical of summer conditions here were *Cheumatopsyche* sp., *Macronema* sp. and *Tricorythus discolor*. *Lestagella penicillata* and *Ephemerelina penicillata* were the typical winter species. During both seasons the indicator species differed from site 3. At site 5, the numbers of simuliids were almost the same in March (60) and August (64). *Tricorythus discolor*, as in site 4 and *Afronurus harrisoni* were the indicator species of summer conditions here. The typical winter species, as in site 4 again, were *Lestagella penicillata* and *Ephemerellina penicillata*.

In a comparison between site 3S, and sites 4S and 5S combined, it was found that two species, *Aphanicerca* sp. and the Hirudinea species were the only ones typical of site 3. However, six species, for example, *Petrothrincus circularis* and *Tricorythus discolor* were typical of the lower sites. Another significant difference in summer was the decrease in the number of simuliids between sites 3S and sites 4S and 5S. During winter, two species were typical of sites 4 and 5 (*Petrothrincus circularis* and *Burnupia capensis*) while there were none at site 3.

A comparison between sites 3S and sites 4W and 5W combined, showed that there was no significant difference between the numbers of simuliids in these two groups. One indicator species, *Burnupia capensis*, was common to the two groups.

Species diversity

Species diversity usually increased in March and decreased in August (Fig. 3). The main reasons for the decrease in winter were the decrease in the number of species present and the increase in the number of simuliids. Site 2 had a very low species diversity in both seasons due to the dominance of the simuliids and the paucity of species at this site. The very high number of simuliids at site 3W (2360 m^{-2}) explains the very low species diversity at this site, although it has more species than did sites 2W, 4W or 5W. The influence of a large number of individuals of a single species can

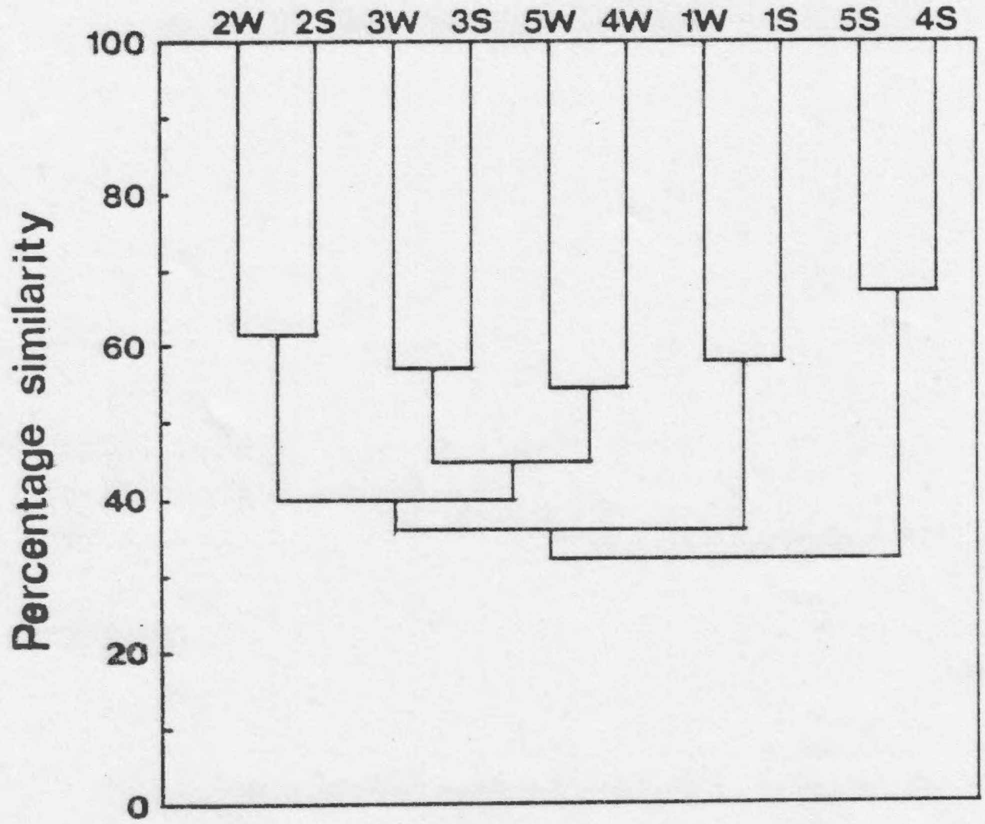

Figure 8 Dendrogram of the similarity matrix of benthic macroinvertebrate numbers at the Palmiet River sampling sites (1-5) in March (S) and August (W).

also be seen at site 5S, where *Tricorythus discolor* depressed the diversity to lower than the winter value (4,19 vs 3,64).

The trend in both winter and summer, down the length of the river, was for the highest species diversity at site 1, a decline at sites 2 and 3, and then an increase to sites 4 and 5 again (Fig. 3).

Using stepwise multiple linear regression analysis, it was found that the only physical and chemical factor significantly correlated with species diversity, was flow rate. Species diversity and flow rate were negatively correlated ($r = -0,349$; $F = 20,61$; 8df; $p < 0,002$), and this trend can be observed in Fig. 3. The correlation probably stems from the influence of the numbers of simuliids on the species diversity index, and will be discussed below.

Cluster analysis

As with the physical and chemical conditions, the faunal samples can be divided into seasons on the ordination plot (Fig. 9). In this case the seasons are separated by the y-axis, but there are no clear upstream or downstream components. At the 50 percent similarity level in the dendrogram (Fig. 8), the samples cluster into five groups, of which sites 1, 2 and 3 are similar seasonally and sites 4 and 5 are similar longitudinally. It is important to note, however (Fig. 8), that site 3S is more similar to sites 4W and 5W, than to sites 4S and 5S. This is indicated by the dashed line in Fig. 9.

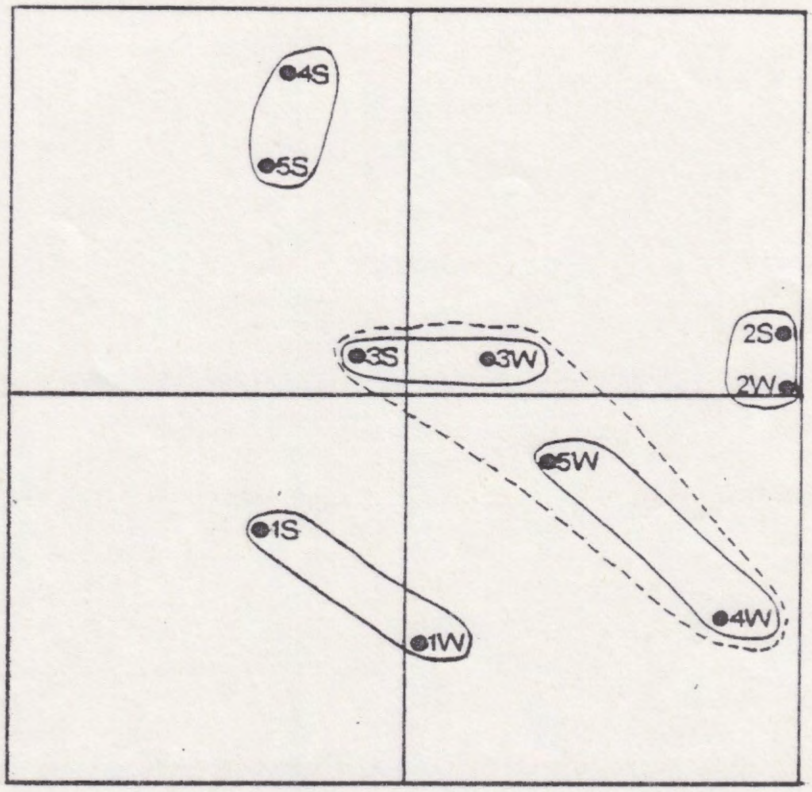

Figure 9 Two-space ordination diagram of the similarity matrix of benthic macroinvertebrate numbers at the Palmiet River sampling sites (1-5) in March (S) and August (W). Groups are as in figure 8 at the 50 percent similarity level. Dashed line indicates the group formed at the 42 percent similarity level in Fig. 8. Stress = 10,8% (acceptable, Levine 1978).

DISCUSSION

Influence of the catchment area

The influence of physical and chemical factors of a river on the composition and abundance of its faunal communities is a well documented phenomenon (see Hynes 1970, for a review). Yet the effect of the catchment area on the physical and chemical factors of the river (and hence on its fauna), has only recently been fully appreciated (Cummirs 1979; Ward & Stanford 1979). This realisation has led to the formulation of the "river continuum concept" (Vannote *et al.* 1980), which emphasises the importance of the catchment area on the gradient of physical and chemical factors. This, in turn, influences the transitional arrangement of faunal communities down the length of a river. The concept, however, also accommodates unnatural disturbances (e.g. dams, pollution), which alter the patterns of community structure. King (1981) and Chutter (1971) have found that the zoobenthos of the stony-bed areas of a river are very sensitive to ecological disturbances and are therefore the communities which best reflect changes in the river's ecological status.

Physical zonation of the catchment area

The three distinct zones in the catchment area (Fig. 2) are readily discernable in the grouping of the physico-chemical conditions in Figs 5 and 6. Except for the obvious seasonal separation of the sampling sites (Fig. 5), they are also grouped into an upstream component (above Grabouw) and a downstream component. Site 3, in turn, is separated from sites 4 and 5. Longitudinal zonation has been ascribed to nutrient levels, and seasonal separation to increased flow and decreased temperature in winter. The high nutrient levels at site 3 and lower (Fig. 3) in the otherwise oligotrophic black waters are probably due to runoff from agricultural land and effluent from Grabouw.

Comparisons with other rivers

The Palmiet River has few species in common with the benthic fauna of the Berg River (Harrison & Elsworth 1958), *Ephemerellina harrisoni* and *Baetis harrisoni* being two major exceptions. In the Berg River the Ephemeroptera made up a large part of the insect fauna, as in the Palmiet River, but the Diptera were not as common. The main trends of decreased numbers of species and diversity in the lower reaches and during winter were also found in the Berg River. Harrison and Elsworth (1958) state that the community structure and its longitudinal variation can be attributed to the silt load of the river. This could explain the dissimilarity between the benthic fauna of the two rivers, since the Palmiet River does not carry a large silt load.

On the other hand, the Palmiet River had 27 species (of 43 recorded in this study) in common with the Eerste River. The single group with the most species in common was the Ephemeroptera (8 species).

Although the rivers arise a few kilometres from each other in the Dwarsberg, 16 Palmiet River species were not recorded in the Eerste River (King 1981). These species mainly belonged to the Coleoptera (5) and Trichoptera (5). The pattern of decreased downstream numbers and diversity was repeated. *Castanophlebia calida*, a species typical of mountain stream conditions in the Eerste River, was also typical of upstream conditions in the Palmiet River. *Burnupia capensis* was a species typical of the lower reaches in both rivers. However, it is important to note that *Afronurus harrisoni* and *Lestagella penicillata*, typical of upper river conditions in the Eerste River, were indicator species at sites 4 and 5. *Lestagella penicillata* is in fact an indicator of mountain stream conditions in the Eerste River. This illustrates the rejuvenated nature of the river just before the estuary and could be due to the steep overall gradient and the rocky nature of the river bed.

However, stricter comparisons between community types, especially with those in the lower, more disturbed reaches of the Eerste River, is almost impossible. King (1981) has shown that dissolved oxygen is the main factor determining changes in the faunal communities of the Eerste River, and listed temperature and pH as two other important factors. All three of these factors, however, remain virtually constant down the length of the Palmiet River, and cannot explain the variation in community structure from site to site and between seasons. Nevertheless, the uniquely mountain-stream-like character of the Palmiet River, to right above the estuary, must be stressed.

Species diversity

In both winter and summer, site 2 had a very low species diversity, despite its proximity to site 1, which had the highest year-round diversity. This is reflected in the cluster analysis (Figs 8 & 9) by its greater similarity to sites 3, 4W and 5W than to site 1. In total, site 2 only supported 9 species in winter and summer, of which the simuliids were the most important, occurring mainly in summer. The possible reason for the consistent low diversity is the position of the sampling site. The site was situated just downstream from a roadbridge, with steep banks supporting a dense canopy of *Eucalyptus* trees. The site is cast in deep shadow all day long, restricting algal growth on the stony bed. This makes the community dependent on allochthonous input from upstream and therefore only supports efficient filter feeders, such as simuliids and chironomids, and general feeders, like *Baetis bellus*.

The negative correlation found between species diversity and flow is a well documented phenomenon (Hynes 1970), and in the present case, the correlation is enhanced by the contribution of the simuliids to the communities. Minshall (1968) has noted that rapid flow reduces faunal numbers drastically, but that species with short life cycles, like the Diptera, recover quickly in slow flow. Chutter (1968) found that the Simuliidae prefer high flow rates, and Hynes (1970) reports that members of this group go into shelter during spates and are rarely swept away. All these factors explain the correlation between the occurrence of the simuliids and the rate of flow (compare Figs 4 & 7). It is also obvious that their contribution to faunal numbers (2630 m^{-2} at site 3W; 1272 m^{-2} at site 2S) can influence the correlation between flow and species diversity.

The winter spates probably *do* have the greatest general effect on species diversity. This is witnessed by the reduction of the number of species at all the stations, although there is an *increase* in the number of simuliids at site 2S and almost no increase at site 5W.

General trends

The main "trend" in the results was that the sampling sites varied more between the seasons than they did along the river in any season. This is especially apparent in the clustering of sites 3, 4 and 5 in both the physico-chemical and faunal analyses (Figs 6 & 9). As discussed above, the severe winter spates were probably the main cause for this seasonal variation and the reduced species diversity at the downstream site. The effect of the spates has therefore more impact on the communities than longitudinal variation down the length of the river.

Despite the generally marked seasonal variation, it is interesting to note that site 3S clusters with four winter sites (3W, 4W & 5W) instead of with sites 4S and 5S. The information statistics tests have also shown that sites 4S and 5S have no typical species in common with site 3S. Further, there was no significant difference in the number of simuliids when site 3S was compared with sites 4W and 5W.

Burnupia capensis was an indicator species common to both groups, as mentioned already. There were no indicator species for winter conditions at site 3.

The similarity between the sites suggests that site 3S is as "impoverished" in summer as it is in winter, when the spates reduce the number of species and of individuals. It is also more similar to the "impoverished" sites 4W and 5W. A possible reason for this is the portion of site 3 below the disturbed agricultural area.

Another clue to the low species diversity is the dominance simuliids as site 3S *despite* relatively low flow rates. The numbers of simuliids are not always correlated to the flow rate as shown by their seasonal constancy at site 5 and their increase at site 2W. Chutter (1969) stresses that other factors, despite flow, could cause an increase in simuliid numbers. He suggests elsewhere (Chutter 1968) that microplankton developing in impoundments above a benthic community, could be a good food source, encouraging the increase of simuliid numbers. Ward and Stanford (1979) also state that the Simuliidae increase their numbers downstream from dams releasing surface water, for the same reason given by Chutter. These facts suggest that in the Palmiet River the increase in simuliid numbers might be due to Monteith dam, just above site 3, or to the pools formed by the TMS ridges. However, more adequate sampling, over an extended period, is needed to verify this suggestion.

In conclusion, it can be seen that the zonations of the catchment area have a clear effect on the physical and chemical conditions of the water. Site 3S suggests that these conditions are reflected by the benthic fauna, whereas the low species diversity at site 2 is almost definitely due to environmental disturbances. These findings can be put in terms of the river continuum concept, but they are described better by Thienemann's principles (Thienemann 1954, quoted by Hynes 1970):

1. Species diversity is proportional to niche diversity.

2. Environmental perturbations decrease the number of species present and increase the number of individuals of species that persist.

3. Environmental stability increases biotic diversity and ecological stability.

Finally, it is clear that the construction of a dam just above the estuary, which will flood large areas of the Kogelberg State Forest, will destroy almost all that is left of unspoilt Palmiet River, leaving only a few kilometres of mountain stream in its natural condition. In effect, the whole of the Palmiet River will then be destroyed; and with that, the last unimpeded perennial river in the Western Cape will be lost.

SUMMARY AND CONCLUSIONS

1. The Palmiet River has a very large annual discharge, when related to its small catchment area. The discharge takes the form of huge winter spates which scour the lower reaches of the river to the bedrock.

2. Samples of macroinvertebrate benthic fauna were taken at five sites along the river, from its headwaters to the lower reaches. Physical and chemical conditions were measured at the same sites at the same time in order to relate changes in these to changes in the benthic fauna. Data were analysed using Bray-Curtis similarity measures, stepwise multiple linear regression analyses and information statistics tests.

3. The catchment area could be divided into three main areas. These variations were reflected in the recorded physical and chemical conditions of the river water.

4. The fauna were dominated by insects of which the simuliids were the single most dominant group.

5. Species diversity indices were lower in winter than in summer, and were higher in upper reaches, than in the lower

reaches. The indices were much influenced by the high numbers of simuliids present.

6. The main trend in the faunal communities was the greater importance of seasonal changes over longitudinal variation. This was only true in the lower reaches of the river, and was probably due to the large winter spates.

7. Summer communities at site 3 were more like winter communities downstream than summer communities. This suggested the possible effect of agricultural development and dams on the river, although the effect was masked in winter.

8. Zonation in the catchment area affects the river, as reflected by the benthic fauna, but the huge winter spates mask these effects in winter.

9. By damming the lower reaches of the Palmiet River, almost all of the unspoilt river will be flooded, and the last unimpeded perennial river in the Western Cape will be lost.

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APPENDIX Numbers of each species caught at the Palmiet River sampling sites in March and August using the Surber sampler (0,25 m^{-2} sampling area).

SPECIES	SAMPLING SITES									
	MARCH					AUGUST				
	1	2	3	4	5	1	2	3	4	5
Hirudinea										
Planaria			32							2
Annelida										
Unidentified sp. 1		4	1	2			1	1		
Mollusca										
Burnupia capensis			11	1						15
Lynmaea columella			1							
Crustacea										
Gammarus sp.	25					9				
Ephemeroptera										
Apprionyx rubicundus	1									
Castanophlebia calida	4	1	1			20			1	
Baetis bellus	3	5	12	7	4		2	48		2
Baetis harrisoni	2		2							
Afronurus harrisoni				14	20				2	
Ephemerellina harrisoni	1									
Lestagella penicillata	2					6		1	30	6
Ephemerellina penicillata								3	23	8
Tricorythus discolor				36	237					
Trichoptera										
Barbarochton brunneum				2						
Petrothrincus circulans	1			47	71				1	34
Cheumatopsyche spp.	2		17	45	23		1	22		2
Orthotrichia sp.							1			2
Polycentropodid sp. 1	1	1	1		1	9				
Macronema sp.				13	3					
Hydroptilid sp. 1				5						
Other larvae		1	17							
Other pupae	1				63	2				

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